# Penetrating the Coulomb barrier

The Breit-Wigner formula for calculating the cross section for any particular resonance is proportional to the square of the De Broglie wavelength. Normally, one thinks of a nucleus as being at rest relative to the lab frame of reference, so that the De Broglie wavelength can also be calculated relative to that frame of reference. However, the correct frame is actually the frame of the nucleus itself. When looking at fusion between positively charged particles in a lattice, a very different situation occurs, as a consequence of the rigidity of the lattice. Because of this rigidity, sound waves travel through the lattice, moving all nuclei in harmony, *including that of the fusing particle*. This is because both particles are charged, and consequently subject to the lattice vibrations. This is not true of neutrons.

As a consequence of these mass movements (waves) in the lattice, it sometimes happens that adjacent nuclei vibrate in phase with one another, especially when both share the same mass and charge. In this situation, the relative velocity of the nuclei is zero, and consequently the De Broglie wavelength of both nuclei, relative to one another is infinite. Therefore the Breit-Wigner cross section is also infinite. This makes fusion possible.

If one wishes to achieve such fusion on a large scale, then it becomes necessary to **maximize** the number of "in phase" pairs of nuclei.

### *The nuclei vibrate in phase when the wavelength of a sound wave in the lattice exactly matches the distance between the nuclei that one wishes to fuse. As the match between the distance and the sonic wavelength improves, the phase difference changes more slowly, increasing the common De Boglie wavelength for longer periods and with it the likelihood of fusion.*

In this situation, millions, billions, or even trillions of nuclei can all share overlapping De Broglie waves, or they could if the whole lattice were vibrating at the maximum frequency. This is essentially a high temperature Bose-Einstein Condensate, or at least very nearly so.

So which frequencies do prevail in such a lattice?

***It turns out that for a body-centred cubic lattice, the Debye temperature corresponds to a wavelength that is about 2% greater than the closest distance between the base lattice atoms. For a face centred cubic lattice, this is about 0.5%.***

From this I draw the very generalized conclusion, that the Debye temperature for a crystalline solid is always determined by the shortest distance between nuclei in that solid, and the velocity of sound in that solid.

Debye temperature of various metals
(see Webelements)

| Element | Ni | Ti | Pd | Al | Mg | Cr | Pt | Au | Fe |
|---|---|---|---|---|---|---|---|---|---|
| Temperature (K) | 427 | 426 | 283 | 423 | 396 | 598 | 234 | 165 | 457 |

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This is also the shortest possible wavelength attainable, as it corresponds to the maximum possible lattice frequency. That means that at best we are 0.5 % short of our goal. Nevertheless, a mere 0.5 % frequency difference, will give rise to very large De Broglie wavelengths, for considerable periods of time.
Presumably as the temperature rises beyond the Debye temperature, more and more atoms vibrate at this maximum frequency, populating it, at the cost of lower frequencies.

***The implication here is that if CF is to be achieved at all, then best results will be attained at temperatures above the Debye temperature of the material comprising the host lattice, provided that the separation of the target nuclei, matches that of the host lattice, and many of the vibrations are aligned in the same direction.***

**This last point is important**. Normal fcc and bcc lattices are symmetrical in several directions. This allows the sought after shortest wavelengths to point in diffeent directions for adjacent cells. Not a desirable situation when one is trying to achieve large De Broglie wavelengths. This problem can be overcome, by using a crystal lattice that is triclinic. In such a lattice, two specific nuclei in each cell will be closer together than any other pair in the cell. This is the same pair for each cell. In other words each cell contibutes a pair of nuclei that will vibrate with the same spatial orientation as the vibrations in adjacent cells, when driven to vibrate at the maximum frequency for the lattice. Furthermore, all nuclei in such a lattice are members of at least one such pair. This means that large sections of the lattice can contain nuclei that all vibrate in the same direction.
It may be therefore that the "special sites" in CF cell cathodes comprise series of lattice cells that are deformed such as to be triclinic. This could be at the surface, or on grain boundaries, or where certain contaminants are present.
It might be possible to "mass produce" such sites by subjecting the cathode to distortion forces e.g. torsion and streching, such as would occur in a helical spring under stress.
These forces however should not permanently deform the cathode by causing crystals to slide across one another, as such movement would relieve the stress on individiual lattice cells, allowing them to return to their normal symmetric shape.
In other words, the cathode should be constantly subjected to some deforming force while in use.
It is interesting to note that deformed cell shapes may well occur during phase transitions in the metal. This means that it might be possible to create a scenario that looks like this:
Loading of the cathode produces an initial phase transition, or distortion due to expansion. Local deformation of the lattice leads to fusion, generating a burst of heat. As the temperature rises above the phase transition point, symmetry reasserts itself, and fusion ceases. Ambient water cools cathode to point where phase transition once again occurs, resulting in deformation, and resultant energy burst. This raises the temperature above the phase transition point again, and the cycle continues ad infinitum (or at least until the fuel runs out).
Most CF experiments have been conducted at atmospheric pressure, hence the temperature remains below 373 K. As luck will have it the Debye temperature of Ni is about 427 K, and is thus not reached in these experiments. That of Pd however is 283 K (10 C), so one might expect to achieve good results in this case.

Yet heavy loading may be necessary for other reasons, such as ensuring that the hydrogen is present as ions rather than as atoms (Thanks goes to either Horace Heffner or Marshall Dudley for this point, I can't remember which).

All of this may lead you to wonder how the Patterson Cell could work at all, if it never reached the Debye temperature while in operation? I suspect that the answer is twofold.

In the first instance, even below the Debye temperature, there will be some in-phase, or nearly in-phase nuclei pairs. Some of these will not be nearest neighbors, but next-to-nearest neighbors, or even further removed.
That this cell (and various others) normally operates below it's optimal temperature, explains why it appears

to work better, as the temperature rises.
In the second instance, I suspect the the physical dimensions of the Patterson beads plays an important role in their success. Specifically, that the thickness of the layer(s) of the metal on the beads, helps to select certain freqencies above others, such that any nuclei separated by a distance inversely proportional to this frequency, will be in phase, and thus amenable to fusion.

In summary, the positive charge on both particles taking part in the fusion process, ensures that they are both "ensnared" in the lattice as it were, ensuring that they can move in phase with one another, and therefore share truly vast De Broglie wavelengths, increasing their capture cross section and leading to fusion.

What follows is even more speculative than what came before.

# Different Types of CF

So far I have expounded upon the consequences of large De Broglie wavelengths for penetration of the Coulomb barrier. Now I would like to look at the possible consequences for what happens after that.

A large capture cross section, hints at extended influence of the nuclear force. If this is so, then this may provide a link across many nuclei, when their shared De Broglie wavelength is large enough. It may be this distributed nuclear force which allows the distribution of momentum across many nuclei simultaneously.

Light nuclei have something to gain by fusion. Heavy nuclei have something to gain by fission. The border line lies in the neighborhood of iron-nickel.

This means that fusion reactions can fall into three categories.



### Fusion forming a single nucleus.

Momentum can be conserved by distributing it over multiple nuclei through mediation of the extended nuclear force. In this case, the newly formed nucleus "takes off at high speed", while a large part of the lattice rebounds in the other direction. This is the same process that occasionally happens during gamma decay of excited states, and is known as the Mössbauer effect. (If I am right about this, then one might well expect the Mössbauer effect to be more pronounced (i.e. a larger spike, and smaller "wings") when a material with a triclinic lattice is heated above its Debye temperature ). An example of this first type of fusion reaction might be

3Li7 + 26Fe56 -----> 29Cu63 + 19.9 MeV (energy appears mostly as kinetic energy of Cu ion).

Another probably more likely when heavy water is used would be

1H2 + 1H2 ----> 2He4 + 23.8 MeV .

The equivalent reaction with 1H1

1H1 + 1H1 ----> 1H2 + e+ + e- + neutrino + .42 MeV

doesn't happen, due to weak force considerations. Which means that when light water is used, the only reactions that 1H1 can undergo, are those with different atoms, e.g.

1H1 + 1H2 ----> 2He3 + 5.5 MeV  or

1H1 + 22Ti50 ----> 23V51 + 8.1 MeV .

When these energetic ions bury themselves in the lattice, layers of these elements are formed at depths characterized by the penetrating power of the ion (usually a few microns).

## Fusion resulting in fission.

When fusion of the intial nuclei yields a positive energy of formation for the new nucleus (i.e. is an **exothermic** process), and this new nucleus is considerably heavier than Fe-Ni, and this excess energy can sufficiently deform the new nucleus, then fission can follow the fusion, resulting in two or more new nuclei, which may or may not be radioactive. This is essentially a general description of the process of which "normal" induced fission of U235 is one example (though a poor one), and

1H2 + 46Pd105 -----> 47Ag*107 + 13.1 MeV (Ag in a highly excited state)

which is immediately followed by an induced fission reaction such as

47Ag*107 -----> 22Ti50 + 25Mn57 + 33.6 MeV (the initial 13.1 MeV forms part of this 33.6 MeV)

another.
Given that radioactive daughter products are rarely detected in CF experiments, it would appear that fission reactions producing many stable daughter products, and little excess energy are more common than those producing only a pair of daughters, and a lot of energy. Such reactions are called transmutation reactions in the literature. See Joe Champion. The balance between energy and transmutation is probably dependent upon the exact structure of the lattice, and the "mix" of "impurity" atoms present.

## Particle exchange reactions

When fusion would be an **endothermic** process, particle exchange can sometimes still result in an exothermic process. In this case, fusion as such cannot occur, but transfer of a smaller subgrouping of particles (e.g. an alpha particle), from one nucleus to the other can result in an energy release. In this case, the resultant energy and momentum is divided among the two resultant nuclei. Examination of the energy released by such processes indicates that most energy is usually released when the transferred particle is a multiple of an alpha particle (i.e. He4, C12, O16). An example is the reaction:

11Na23 + 82Pb206 -----> 13Al27 + 80Hg202 + 11.2 MeV (alpha transfer)

Whereas the reaction:

11Na23 + 82Pb206 -----> 93Np229 - 67 MeV

doesn't work at all, because it is endothermic. Consequently induced fission reactions of Neptunium do not occur as no Neptunium is formed (i.e. no type 1 or 2 reactions).

## Energy dispersion

Each of the three reaction types above produces energetic positively charged particles. It is generally recognized that such particles have very little penetrating power, and hence would not normally be directly detected outside of the vessel in which they are produced. However such particles must divest themselves of their kinetic energy eventually, and usually do this by dislodging electrons from atoms, in the course of their passage. Some of the electrons will be inner-shell electrons, which will result in the production of x-rays. The energy of these x-rays, will be dependant upon the material through which the initial particle travels. In the case of electrolysis cells, this material would either be cathode material or water. If it is water, then the highest energy x-ray that could be produced would be that from the oxygen atom, which is about 500 eV. As x-rays go, this is what is known as a very "soft" x-ray, and it too has very low penetrating power, hence would unlikely be detected outside of the reaction vessel. On the other hand, x-rays resulting from interactions with the metal of the cathode, would be more energetic. For a Nickel cathode, one might expect x-rays of at most 8.3 keV, and for Pd 23.8 keV. These last should be detectable outside the reaction vessel, in a working cell.

## Acknowledgements

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Thanks go also to Chubb & Chubb, for introducing the concept of fusion in a Bose-Einstein condensate. (At least that's where I first heard about it).

And to all others who have in their own way contributed.

Comments: Please send comments to Robin van Spaandonk